Climate prediction for climate services: a new paradigm in climate research and modelling

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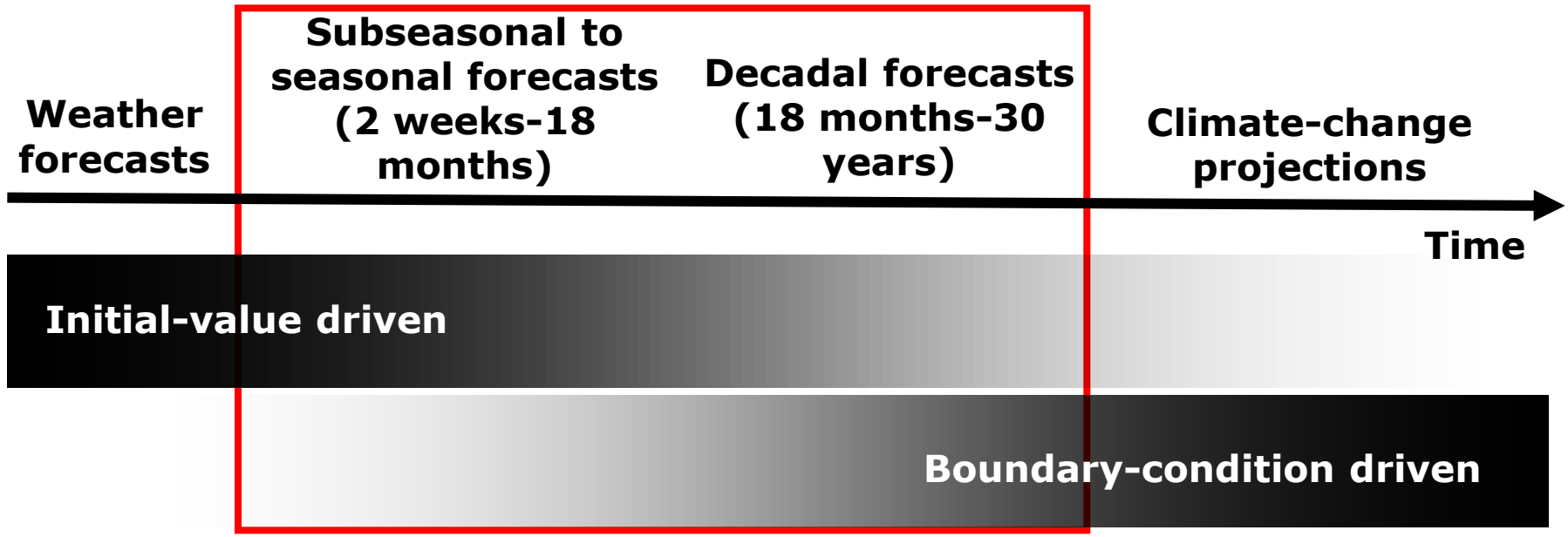
Prediction on climate time scales

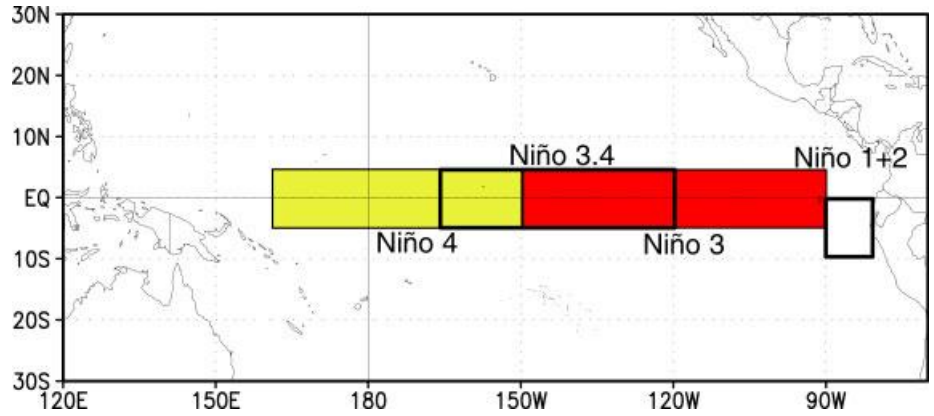
Progression from initial-value problems with weather forecasting at one end and multi-decadal to century projections as a forced boundary condition problem at the other, with climate prediction (sub-seasonal, seasonal and decadal) in the middle. Prediction involves initialization and systematic comparison with a simultaneous reference.

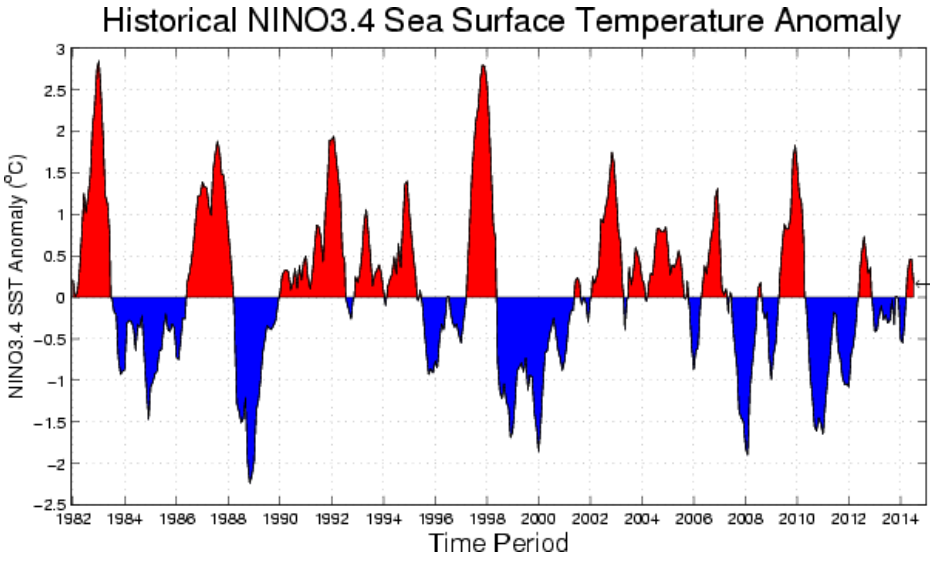


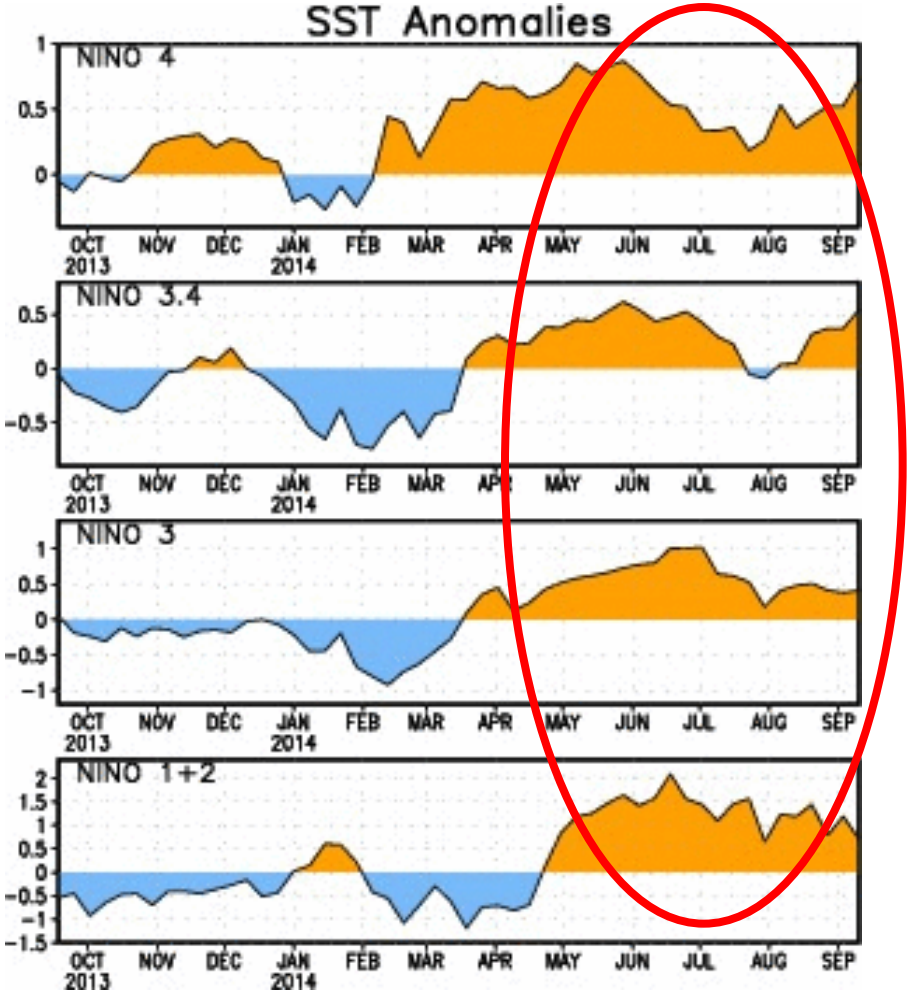
Adapted from Meehl et al. (2009)

El Niño-Southern Oscillation (ENSO)

Sea surface temperature anomalies from the CPC/NCEP analysis for the four Niño regions: El Niño in 2014



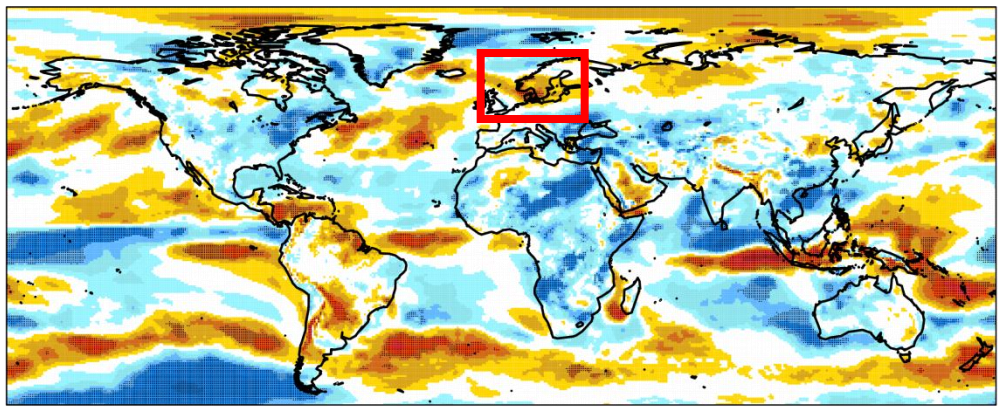


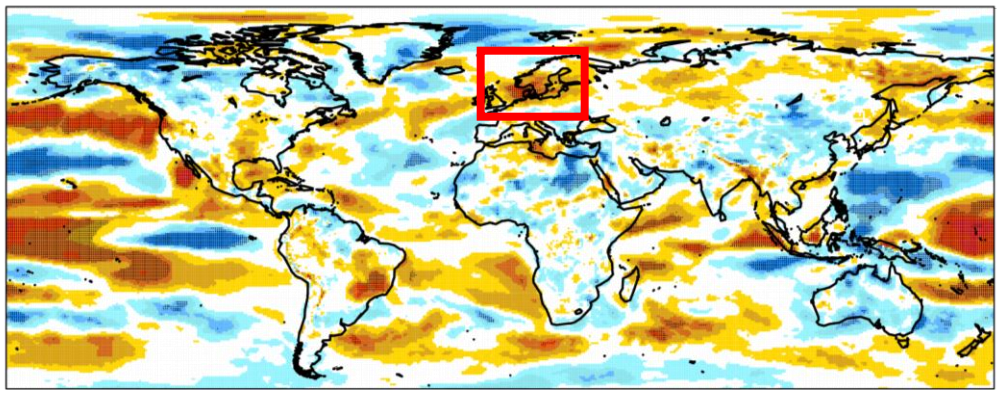


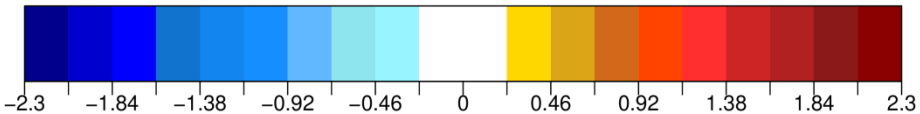
Wind and ENSO

Change in normalised 10-metre wind speed between El Niño (top) and neutral years for SON; for La Niña (bottom).

ERA-Int over 1979-2013 stratified using the Niño3.4 (5ºN-5ºS, 120º-170ºW) SST index with a 0.5 K threshold.

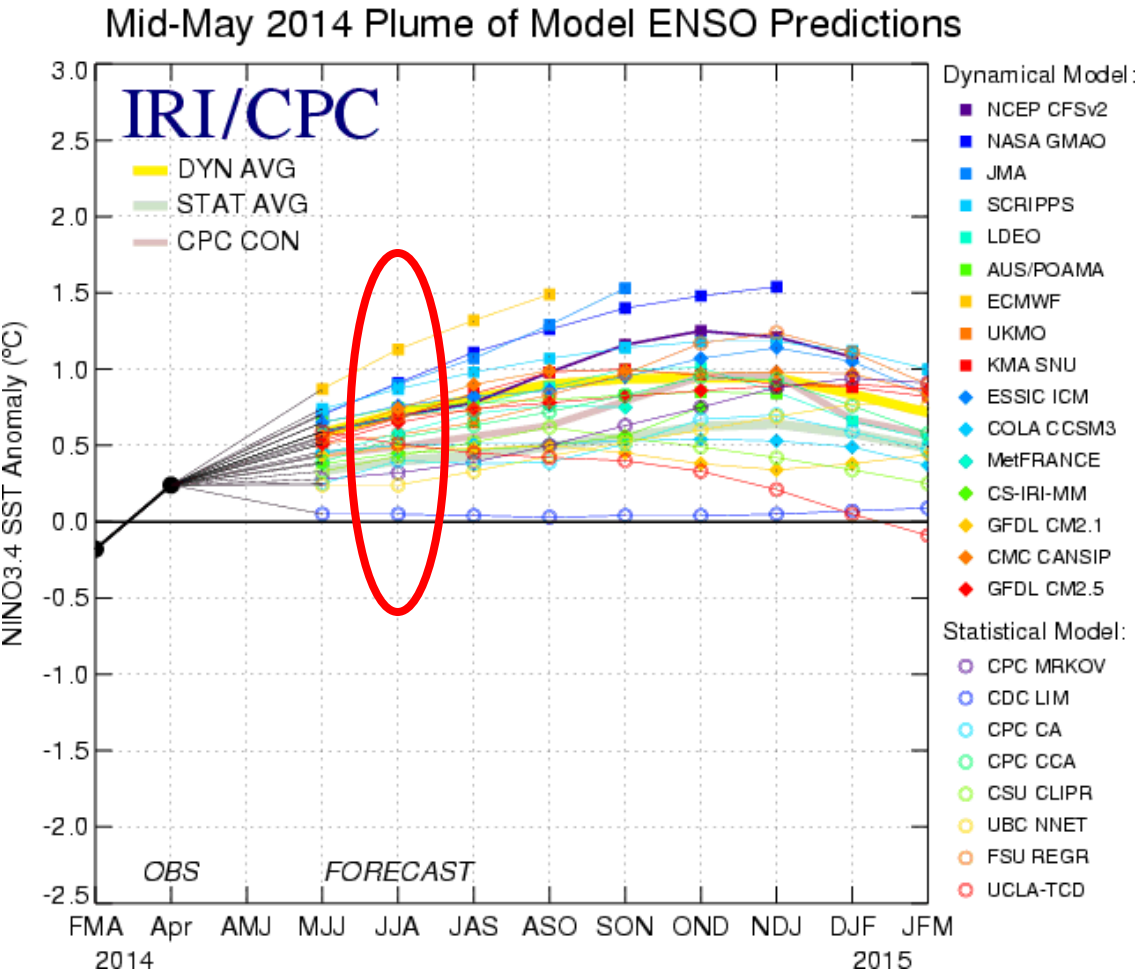


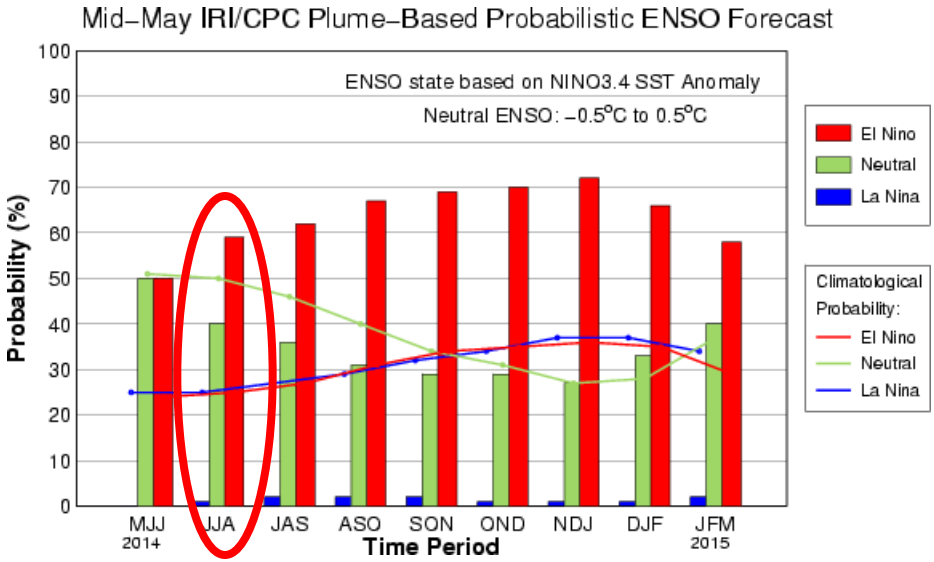




Seasonal forecasting

2014 ENSO predictions: May start date





Climate services: wind energy

What is actually requested in terms of forecasts:

- Forecasts for locations where the mean is large (wind speed above a threshold), and both variability (something to predict) and skill (something useful to say) are high
- Need energy generated over a period (month, season, etc), with uncertainty estimates, at the wind farm level
- Information for off-shore maintenance (at least 3 weeks lead time)
- Also, energy and consumption in other regions to balance network
- Take into account
  - Management strategies
  - Development plans

Some of the things missing

- Better understanding of the impact models, and the best way to adapt them to the useful climate information available
- Bias correction, calibration, combination of the forecasts
- Downscaling, when necessary
- Documentation (some stakeholders are used to the IPCC calibrated language, which is different to the climate forecasting language), demonstration of value and outreach
- The EUPORIAS FP7 project, working alongside the SPECS project, is considering solutions to address some of these problems.

EUPORIAS

Back to the wind energy problem

To satisfy the users' requirements for sub-seasonal to seasonal forecast information:

- High-frequency wind forecasts at ~100 metre height
- Bias-corrected and calibrated forecast data, i.e. whose statistical properties mimic those of the data measured at the wind turbine height -> Bias correcting and calibrating high-frequency data is extremely complicated and could destroy the little skill available

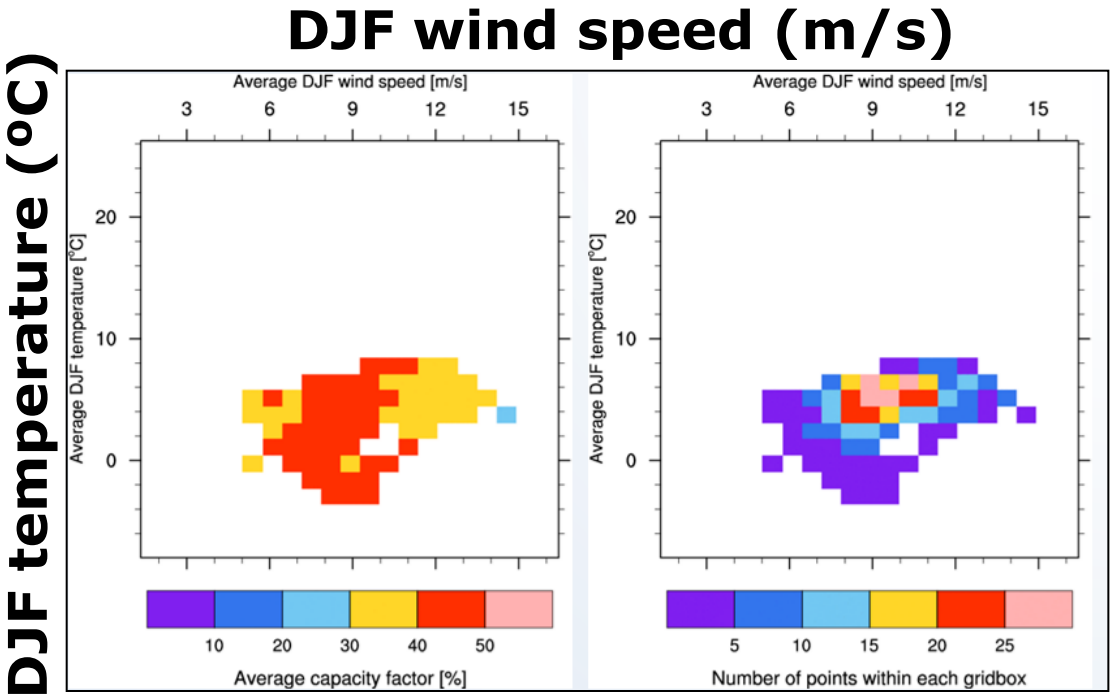
On top of this:

- Local measurements are not long
- They are not even made available

Adapting impact models

Impact surfaces of a simple wind-energy model over the North Sea for DJF as function of the mean seasonal 10 m wind speed and temperature.

(Left) Capacity factor (average power generated divided by the maximum power of a specific turbine) estimates obtained using the XXth Century Reanalysis, a Rayleigh function to estimate high-frequency winds from mean daily values and a wind profile power law to obtain 100 m winds from 10 m winds. (Right) Frequency of occurrence of each bin.



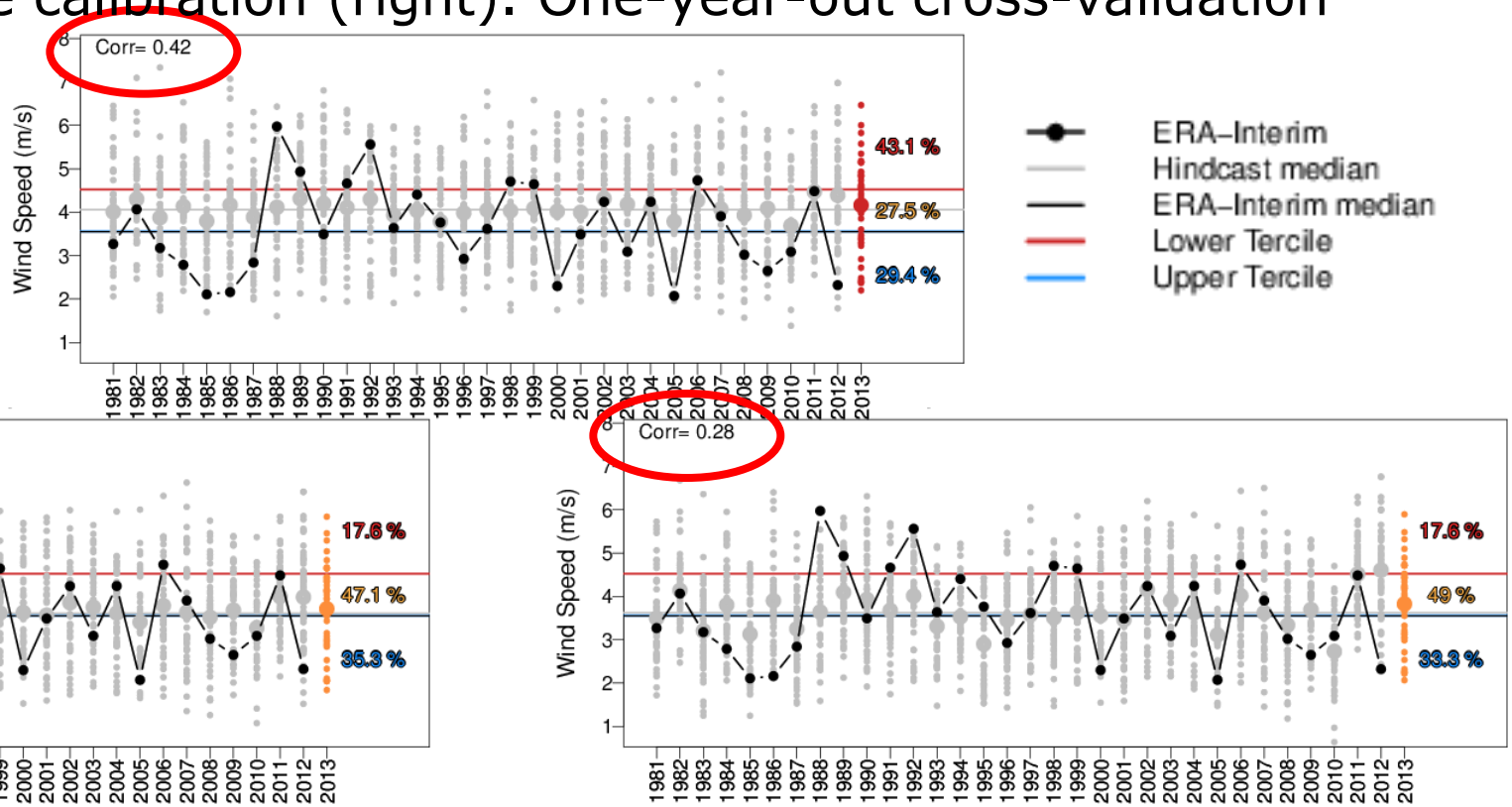
It only needs seasonal-average bias-corrected forecast data to make predictions of the capacity factor!

D. MacLeod
(Univ. Oxford)

Bias correction and calibration

Bias correction is unavoidable, but it has an impact on skill. Bias correction and calibration have different effects.

DJF 10-m wind speed ECMWF S4 predictions over the North Sea starting in November. Raw output (top), bias corrected (simple scaling, left) and ensemble calibration (right). One-year-out cross-validation applied.



V. Torralba (IC3)

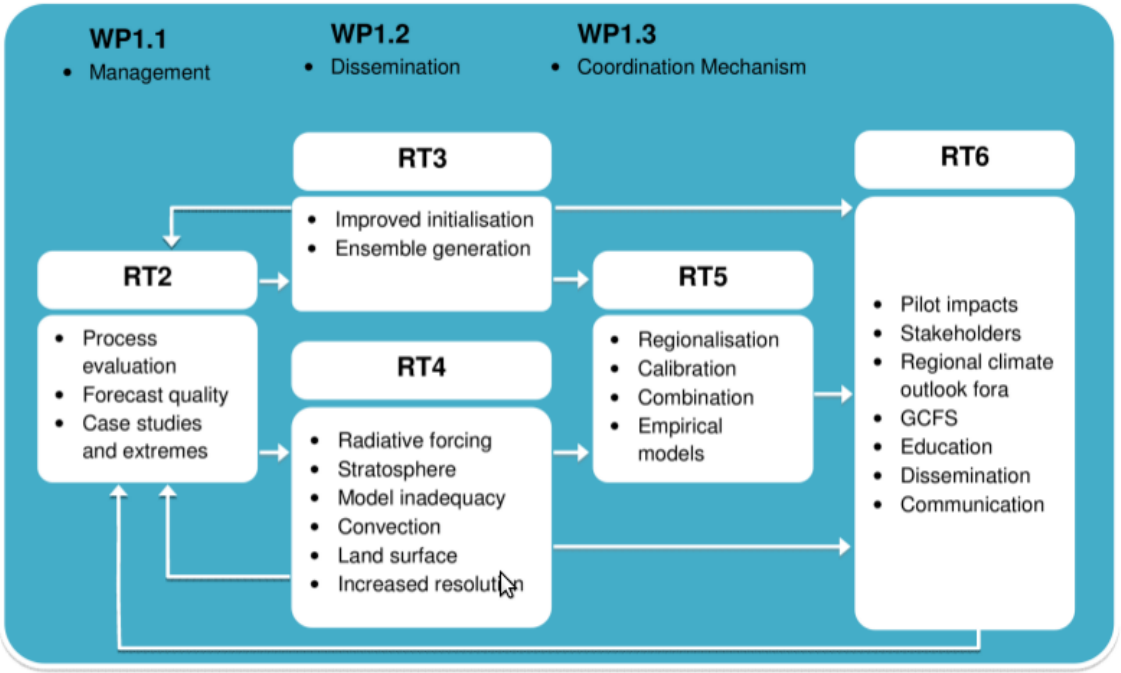
Some open fronts to improve forecasts

- Work on initialisation: initial conditions for all components (including better ocean), better ensemble generation, etc. Link to observational and reanalysis efforts.
- Model improvement: leverage knowledge and resources from modelling at other time scales (improve sea ice, treatment of volcanic and anthropogenic aerosols, vegetation and land, etc); drift reduction; more efficient codes and adequate computing resources.
- Calibration and combination: empirical prediction (better use of current benchmarks), indigenous knowledge.
- Forecast quality assessment: scores closer to the user, reliability as a main target, process-based verification.
- More sensitivity to the users' needs: going beyond downscaling, better documentation (e.g. use the IPCC language), demonstration of value and outreach.

SPECS FP7

SPECS will deliver *a new generation of European climate forecast systems, including initialised Earth System Models (ESMs) and efficient regionalisation tools to produce quasi-operational and actionable local climate information over land at seasonal-to-decadal time scales with improved forecast quality and a focus on extreme climate events, and provide an enhanced communication protocol and services to satisfy the climate information needs of a wide range of public and private stakeholders*.

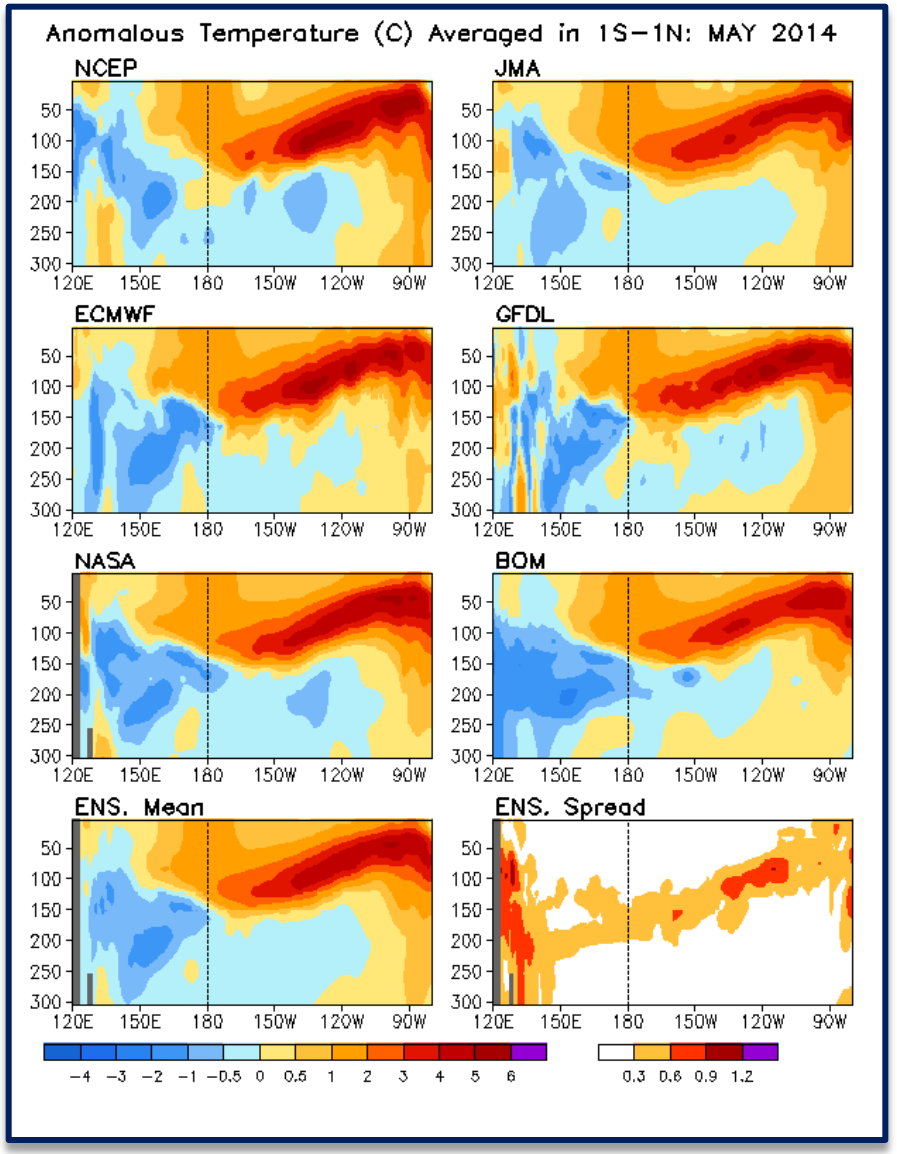
Forecast System	Project Partners
CNRM-CM5	CNRM, CERFACS
EC-Earth	KNMI, SMHI, IC3, ENEA
IFS/NEMO	ECMWF, UOXF
IPSL-CM5	CNRS
MPI-ESM	MPG, UniHH
UM	UKMET



SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

Initialisation

- Real-time ocean analysis comparison. Temperature anomalies along the Equator based on 1981-2010 climatology.
- Large spread in real-time initial conditions.
- Good observations of the whole system are absolutely fundamental for accurate prediction.

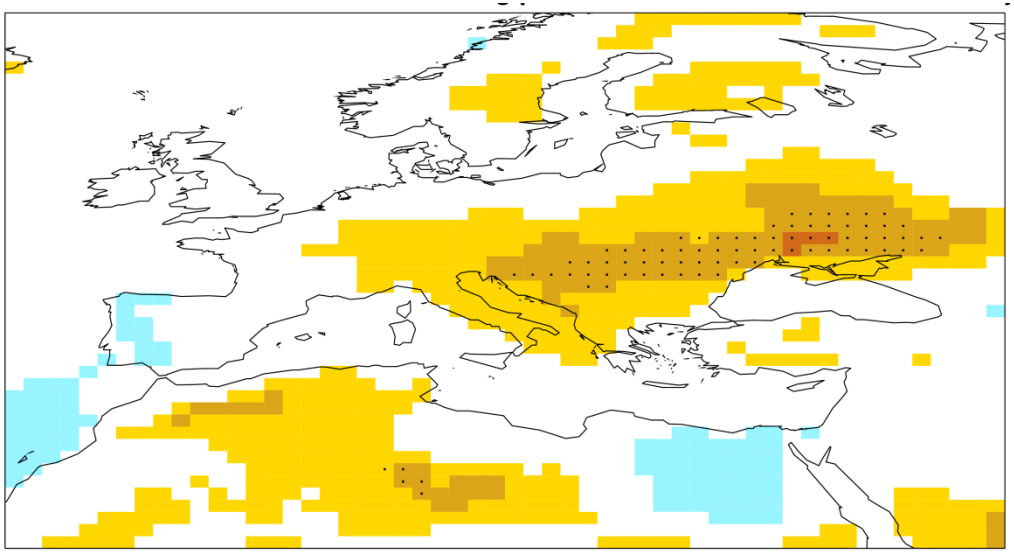


Y. Xue (CPC)

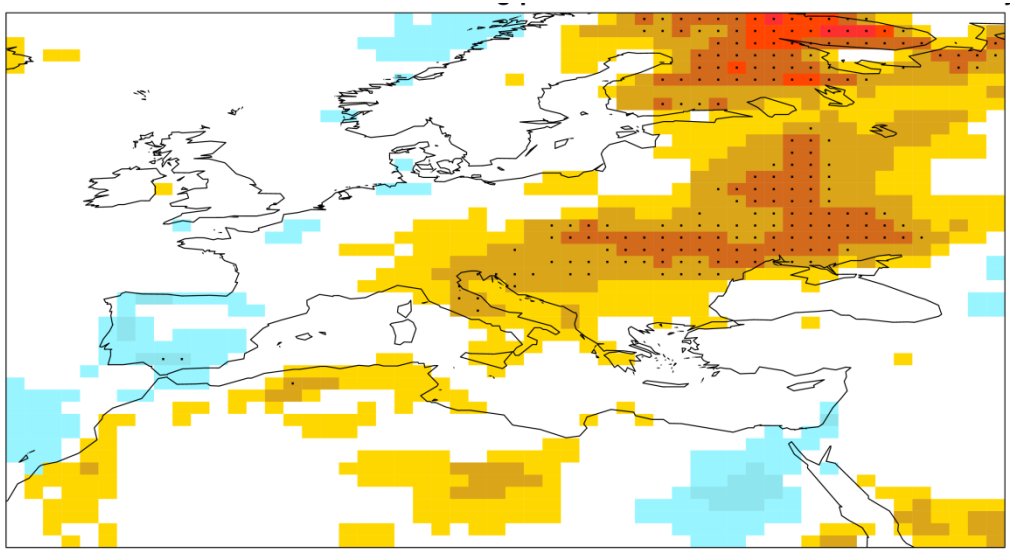
Impact of initialisation: land surface

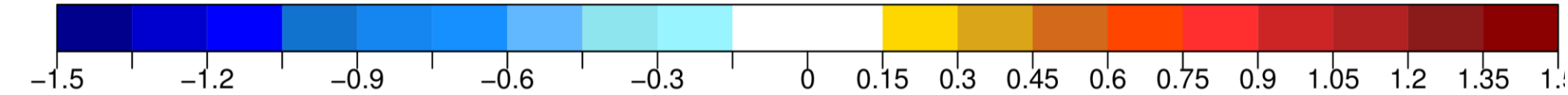
Difference in the correlation of the ensemble-mean near-surface temperature from two experiments, one using a realistic and another a climatological land-surface initialisation. Results for EC-Earth2.3 started every May over 1979-2010 with ERAInt and ORAS4 initial conditions and a sea-ice reconstruction.

Difference for monthly mean T



Difference for monthly mean daily Tmax





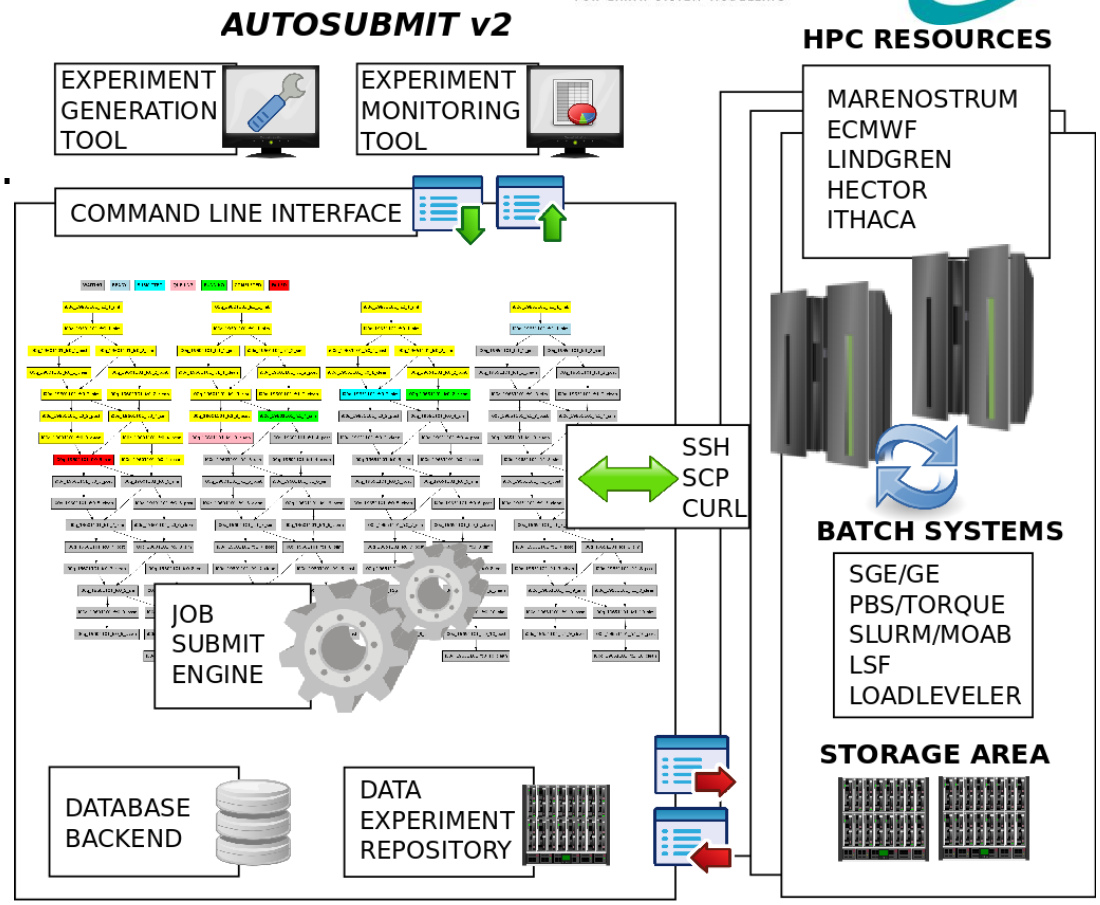
Prodhomme et al. (2014)

Workflows and multi-platform computing

Autosubmit acts as a wrapper to run a climate experiment on a HPC. The experiment is a sequence of jobs that it submits, manages and monitors. When a job is complete, the next one can be executed.

- Divided in 3 phases: ExpID assign, experiment creation, run.
- Separation experiment/autosubmit codes.
- Config files for autosubmit and experiment.
- Database to store experiment information.
- Common templates for all platforms.
- Recovery after crashes.
- Dealing with a list of schedulers and communication protocols.

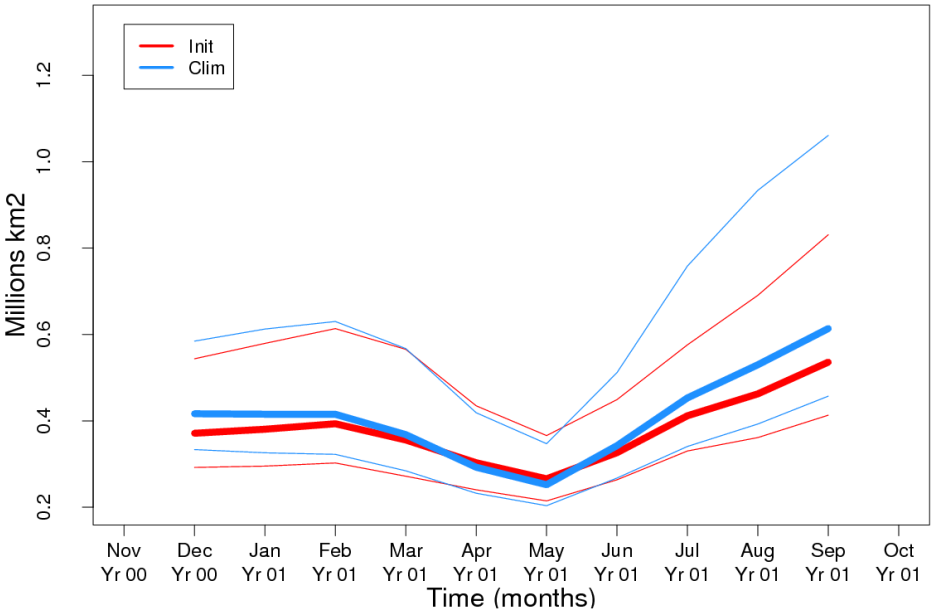
Each job has a colour in the monitoring tool: yellow=completed, green=running, blue=pending, etc.



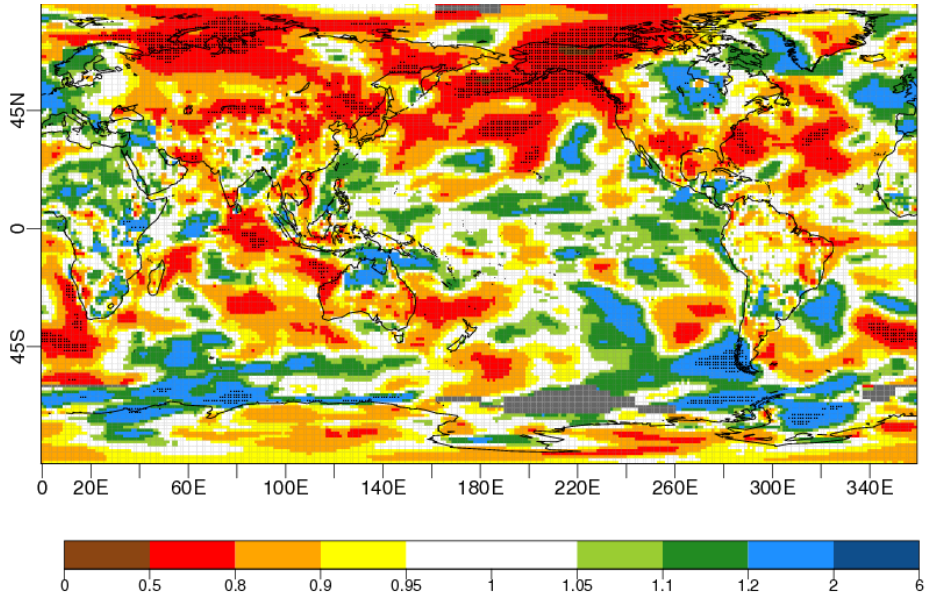
Impact of initialisation: sea ice

Predictions with EC-Earth2.3 started every November over 1979-2010 with ERAInt and ORAS4 initial conditions, and a sea-ice reconstruction. Two sets, one initialised with realistic and another one with climatological sea-ice initial conditions. Substantial reduction of temperature RMSE in the northern high latitudes when using realistic sea-ice initialisation.

RMSE Arctic sea-ice area



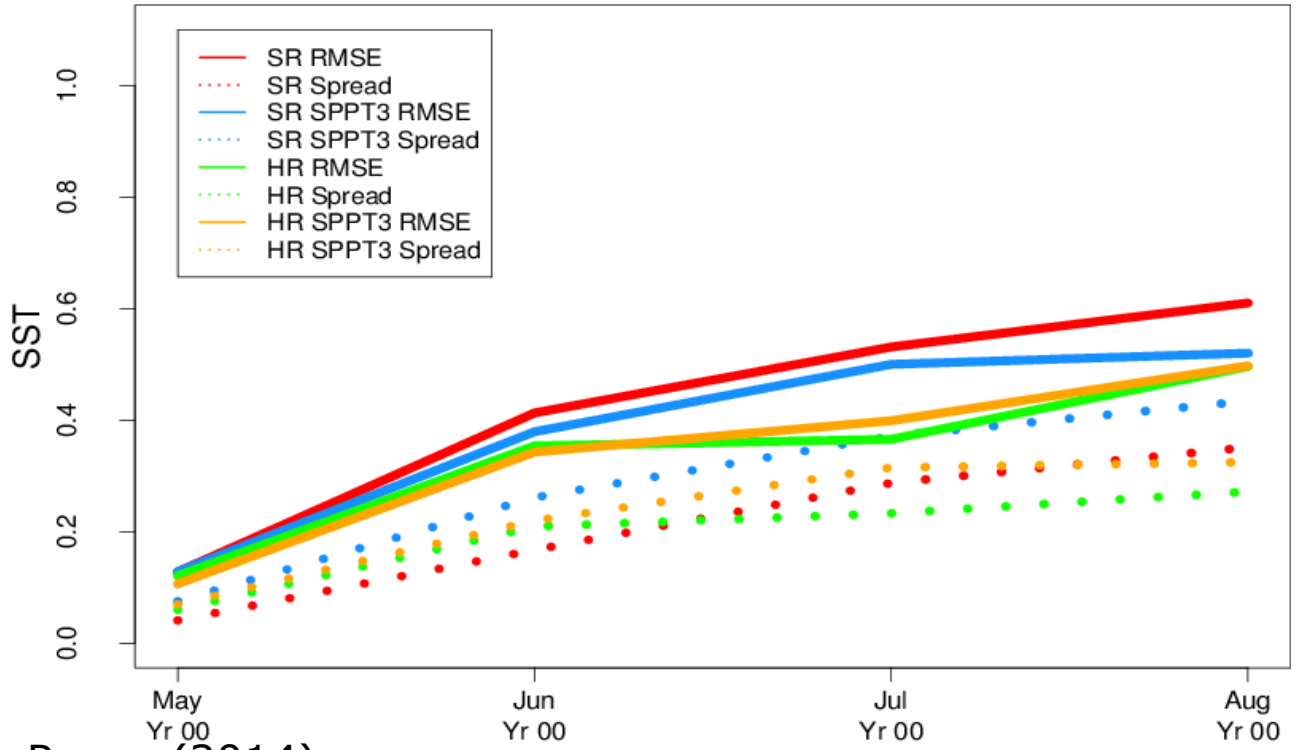
Ratio RMSE Init/Clim hindcasts 2-metre temperature (months 2-4)



Guemas et al. (2014)

Increase in resolution: stochastic physics

RMSE and spread of Niño3.4 SST (versus ERSST) from EC-Earth3 simulations: standard resolution (**SR**, **T255/ORCA1**), high resolution (**HR**, **T511/ORCA025**) without and with stochastic physics (**SPPT3**). May start dates over 1993-2009 using ERA-Interim and GLORYS and ten-member ensembles.

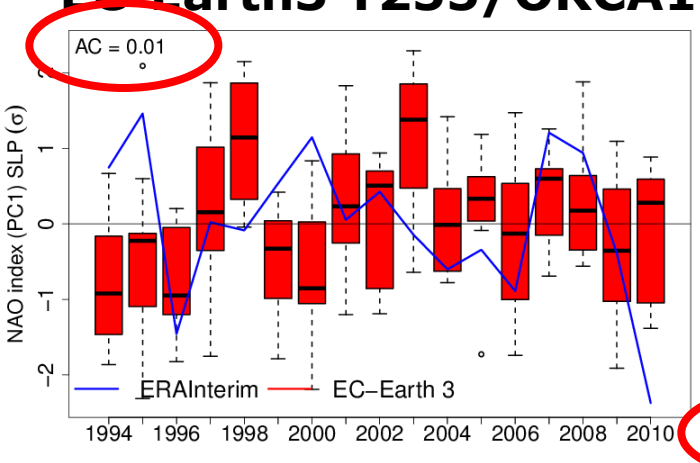


Batté and Doblas-Reyes (2014)

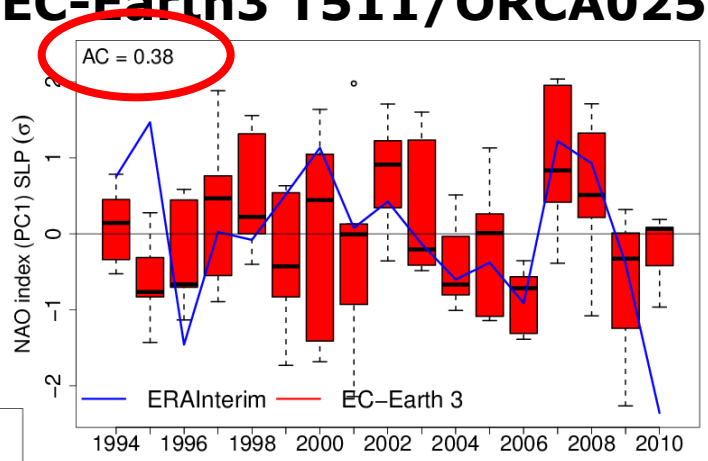
Predicting NA atmospheric circulation

Predictions of DJF NAO with **EC-Earth3 standard and high resolution** and ECMWF S4 started in November over 1993-2009 with ERA-Interim and GLORYS initial conditions and five-member ensembles. Correlation of the ensemble mean on top left.

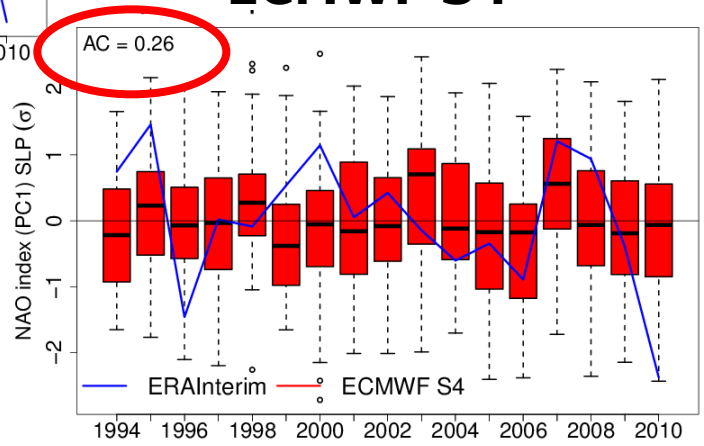
EC-Earth3 T255/ORCA1



EC-Earth3 T511/ORCA025



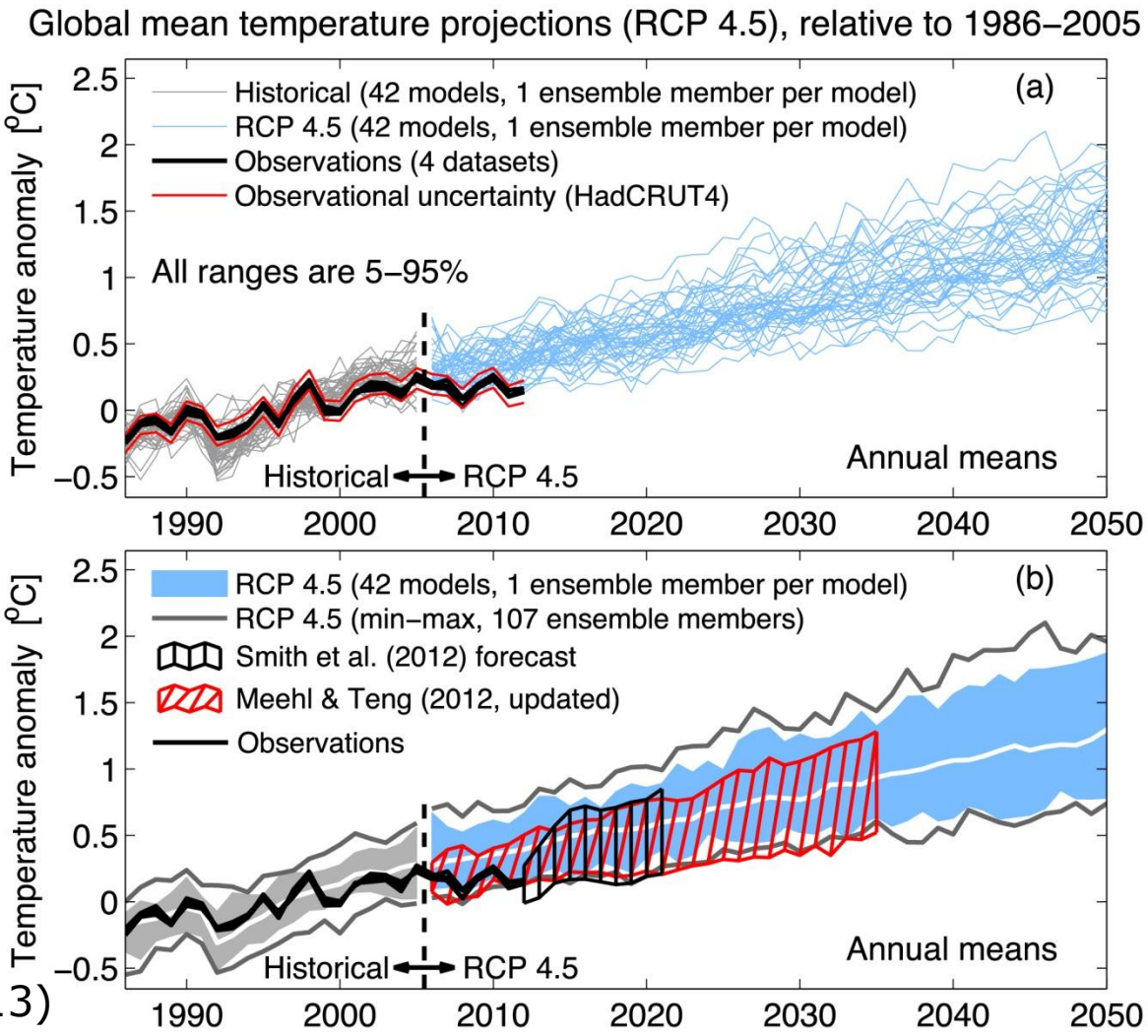
ECMWF S4



Batté et al. (2014)

CMIP5 predictions and projections

Annual-mean global-mean temperature predictions and projections from CMIP5.



IPCC AR5 WGI (2013)

Decadal prediction

Multi-model real-time decadal prediction exchange already established with IC3's participation. Very simple approach: research exercise, learn from it; prevent over-confidence from a single model; equal ownership.

http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/decadal-multimodel

Multi-model decadal forecast exchange

The Met Office coordinates an informal exchange of near-real time decadal predictions. Many institutions around the world are developing decadal prediction capability and this informal exchange is intended to facilitate research and collaboration on the topic.

The contributing prediction systems are a mixture of dynamical and statistical methods. The prediction from each institute is shown below, alongside an average of all the models. When possible, observations for the period of the forecast are also shown. Currently three variables are included: surface air temperature, sea-level pressure and precipitation. These are shown as differences from the 1971-2000 baseline. More diagnostics, including ocean variables are planned for the future. Please use the drop-down menus below to explore the data collected to date.

This work is supported by the European Commission SPECS project.

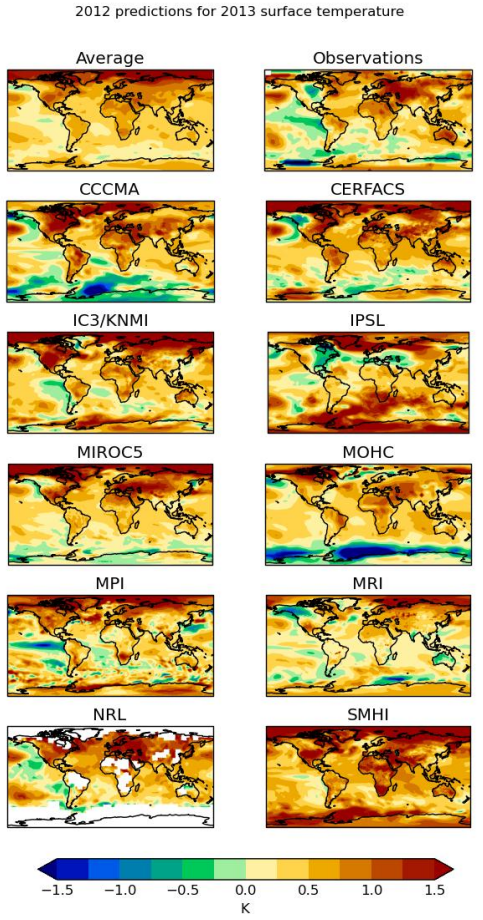
SPECS

To learn more about decadal forecasts at the Met Office, see our current decadal forecast.

Images last updated 2014-06-25

Issued: 2013 | Period: year 1 | Element: surface air temperature

Decadal forecast exchange 2013 predictions for year 1 surface air temperature

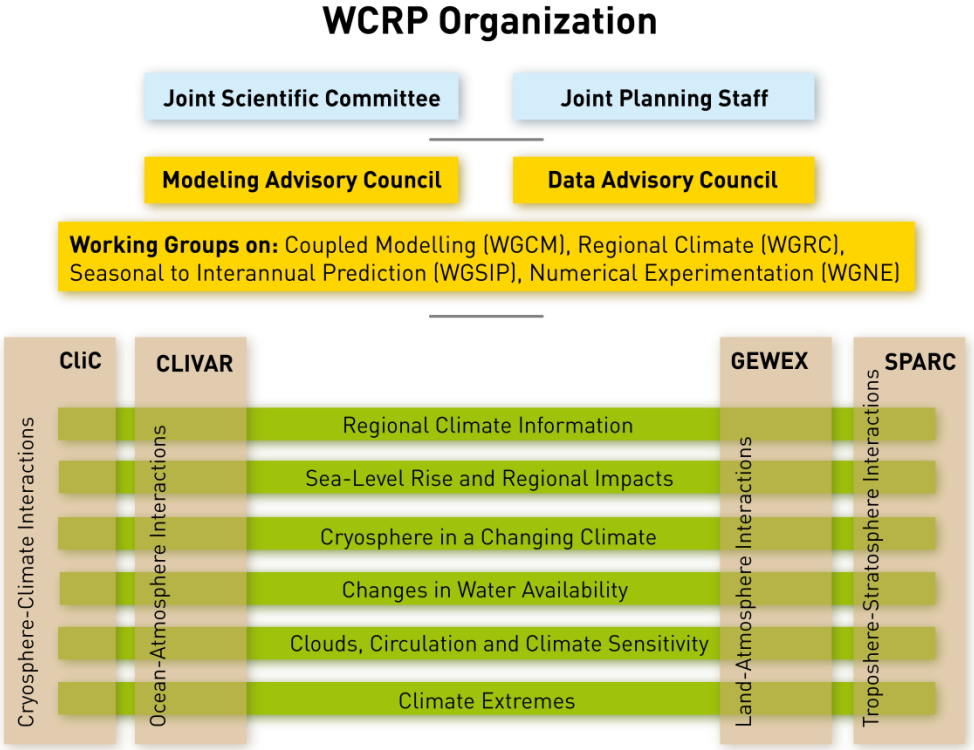


Summary

- Sub-seasonal and seasonal forecasting (s2s) are becoming well established operational activities with a solid research base and an increasing application in climate services and adaptation. Decadal is starting.
- The demand of action-relevant climate information on s2d time scales is growing. However, what forecasters provide is far from what the users demand (even in the absence of skill).
- Bias correction, calibration and combination are essential in the successful application of s2d climate information.
- EUPORIAS, SPECS and many other projects, along with the WWRP and WCRP initiatives (S2S, WGSIP, PPP), work together to bridge the gap and illustrate usefulness.

WCRP and the Grand Challenges

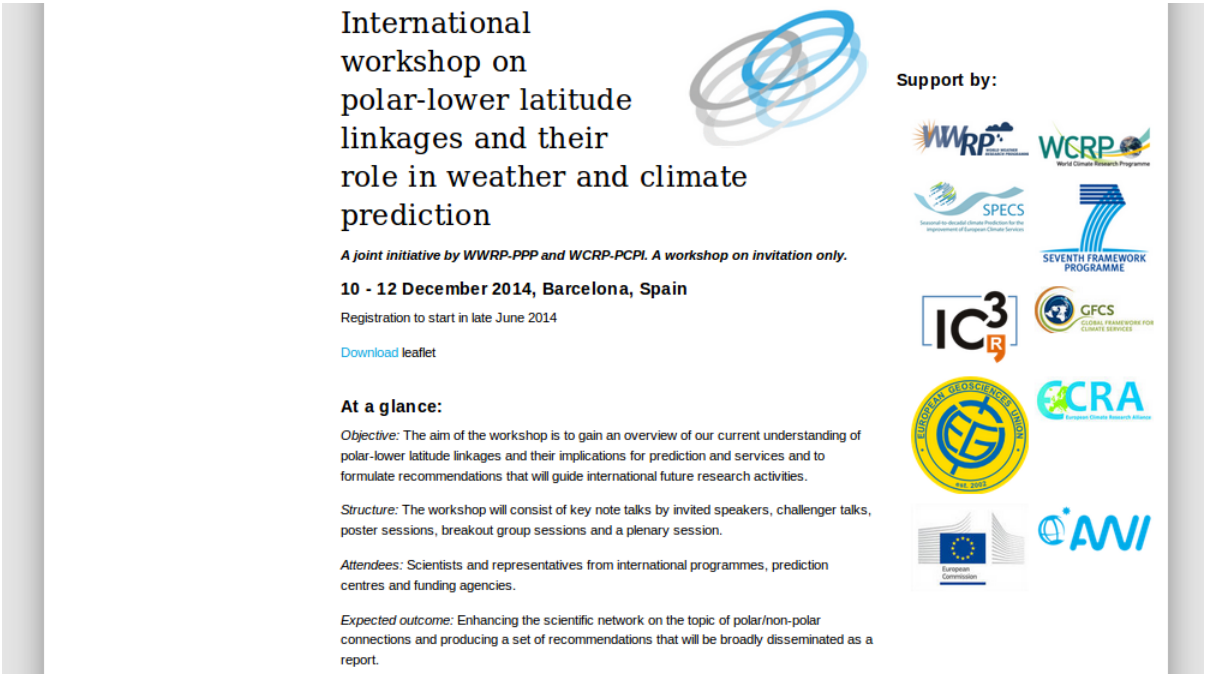
- E.g. Grand Challenge on Regional Climate Information: What gaps in our scientific understanding and information, if addressed, would maximise the value content of regional climate information?
- Decadal prediction and biogeochemistry (including air quality at local scales and impact of volcanic aerosol) chosen as targets for new fast-track WCRP-IPCC activities.



THORPEX legacy projects

The WWRP/WCRP Polar Prediction Project (PPP) promotes cooperative research enabling improved prediction services for the polar regions, on time scales from hourly to seasonal. **This is the hourly to seasonal research component of the WMO Global Integrated Polar Prediction System (GIPPS)**, and complementary to WCRP-PCPI.

WGSIP contributes to the links between polar and non-polar regions (workshop in December) and the organisation of YOPP.



International workshop on polar-lower latitude linkages and their role in weather and climate prediction

A joint initiative by WWRP-PPP and WCRP-PCPI. A workshop on invitation only.

10 - 12 December 2014, Barcelona, Spain

Registration to start in late June 2014

Download leaflet

At a glance:

Objective: The aim of the workshop is to gain an overview of our current understanding of polar-lower latitude linkages and their implications for prediction and services and to formulate recommendations that will guide international future research activities.

Structure: The workshop will consist of key note talks by invited speakers, challenger talks, poster sessions, breakout group sessions and a plenary session.

Attendees: Scientists and representatives from international programmes, prediction centres and funding agencies.

Expected outcome: Enhancing the scientific network on the topic of polar/non-polar connections and producing a set of recommendations that will be broadly disseminated as a report.

Support by:

Some final thoughts

- When dealing with other communities, weather, chemistry and climate research should take into account:
  - Responsibility
  - Sensitivity
  - Credibility
  - Liability